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CAPABILITIES OF A FOUR-CHANNEL TELEMETRY SY

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National Aeronautics and Space Administration

HOUSTON, TEXAS

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PROJECT APOLLO

CAPABILITIES OF A FOUR-CHANNEL TELEMETRY SYSTEM

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1.0 SUMMARY:

This report concerns design and capabilities of a 4-channel telemetry modulation system for use in the Apollo R and D boilerplate and airframe test vehicles. The equipment specifications and mechanical drawings were generated by the Telemetry Systems Section of Instrumentation and Electronic Systems Division (IESD). Certain of the qualification tests were accomplished by the contractor, Sonex, Inc., in association with personnel from the Telemetry Systems Section, while other tests were conducted in-house at MSC.

1.1 DESCRIPTION OF SYSTEM:

1.1.1 The system consists of four high-level, differential input subcarrier oscillators operating on IRIG channels 12 through 15; an isolated output composite signal amplifier; a mounting chassis with resistive pre-emphasis network and a moisture-proof container for the entire system.

1.1.1.1 The subcarrier oscillators operate with a deviation of 96% of the IRIG channel bandwidth with analog input signals of zero to five volts peak-to-peak. Each SCO is provided with an internal SPDT relay to provide for inflight calibration.

1.1.1.2 The composite signal amplifier provides a completely isolated output signal, adjustable from the top of the unit.

1.1.1.3 The mounting chassis provides a mounting surface for the oscillators and amplifier, all interconnecting wiring and the resistive pre-emphasis network.

1.1.1.4 The closed sheet metal box provides a moisture-proof enclosure for the remainder of the components. The cover of the box is provided with a LennonLights Humidity indicator and a dessicant container.

1.2 MECHANICAL FEATURES:

The subcarrier oscillators and the amplifier are completely encapsulated in Emerson and Cummings Eccofoam - FP and are secured to a rugged machined aluminum chassis by means of two 4-40 stainless steel mounting screws. The moisture-proof enclosure is an aluminum weldment which has been ruggedized by the addition of stiffening members along each side. The box closure is ~~a~~effected by means of a flat, vibration damped, aluminum plate (which holds the dessicant and humidity indicator) and a neoprene rubber gasket.

2.0 TESTS CONDUCTED:

The tests that were conducted were those for type qualification of Apollo R and D instrumentation for airframe vehicles (see IESD Document 19-1, Part 3). In some cases, the Telemetry Systems Section has made the specification more severe than IESD requirements in an effort to improve the accuracy of telemetry data, make a more versatile system, and to make a more sensible specification (e.g., IESD Document 19-1 does not require the equipment to operate during humidity tests, but the Telemetry Systems Section specifies equipment operation during humidity tests).

2.1 ELECTRICAL BENCH TESTS:

2.1.1 SHORT TERM STABILITY:

The system was connected for operation at room ambient temperature and +28 vdc was applied to the package. After 15 minutes of operation, stimulus voltages were applied to each SCO and center frequency and bandedges were recorded. Each unit was within the 1.0% dbw setup tolerance.

2.1.2 SUPPLY VOLTAGE SENSITIVITY:

The supply voltage was varied ± 4 vdc around +28 vdc and center frequency and bandedges were recorded. Worst case change was less than 0.12% dbw. The specification allows 0.75% maximum.

2.1.2.1 SYSTEM CURRENT DRAIN:

Current drain at each supply voltage was recorded. Every effort was made to maintain power consumption at a minimum level. At +32 vdc (worst case), power consumption was less than 3.5 watts (102 ma at ambient temperature).

2.1.3 SOURCE IMPEDANCE SENSITIVITY:

The input leads to each SCO were open circuited and then short circuited through approximately 48 inches of unshielded, 28 awg wire. The zero stimulus frequency (LBE) was recorded in each case. Frequency change on all units was less than 0.5% dbw. The specification allows 1.0% dbw.

2.1.4 OUTPUT AMPLITUDE:

The amplitudes of each individual output (into the pre-emphasis network) could not be read directly. Therefore, the amplitudes were measured at the test points of each oscillator. Any change in amplitude at this point would reflect a proportional change at the output pin of the SCO connector. The test point voltages are recorded for each supply voltage.

2.1.5 LINEARITY:

Stimulus voltages in 0.500 vdc steps, from zero to five vdc were applied to the input of each SCO. Output frequency was recorded for each step. An ideal line through the endpoints was then calculated for each SCO. Deviations from this line were recorded. Linearity: deviation from a line through the end points shall be less than 0.5% dbw.

	Stimulus	Actual	Ideal	Actual - Ideal	
10.5kc	5.0030 vdc	11253 cps	11253 cps	0	% dbw
	4.5030 vdc	11102 cps	11102.2 cps	-0.014	"
	3.9996 vdc	10951 cps	10951.4 cps	-0.027	"
	3.5006 vdc	10801 cps	10800.6 cps	+0.027	"
	3.0000 vdc	10650 cps	10649.8 cps	+0.014	"
	2.4990 vdc	10499 cps	10499 cps	0	"
	1.9992 vdc	10349 cps	10348.2 cps	+0.055	"
	1.4974 vdc	10197 cps	10197.4 cps	-0.27	"
	0.9984 vdc	10047 cps	10046.6 cps	+0.027	"
	0.5030 vdc	9897 cps	9895.8 cps	+0.079	"
	0.0000 vdc	9745 cps	9745 cps	0	"
14.5kc	5.0030 vdc	15547 cps	15547 cps	0	"
	4.5030 vdc	15339 cps	15338.4 cps	+0.029	"
	3.9996 vdc	15129 cps	15129.8 cps	-0.038	"
	3.5006 vdc	14922 cps	14921.2 cps	+0.038	"
	3.0000 vdc	14713 cps	14712.6 cps	-0.019	"

	Stimulus	Actual	Ideal	Actual - Ideal	
14.5kc	2.4990 vdc	14505 cps	14504.0 cps	+0.048	%dbw
	1.9992 vdc	14297 cps	14295.4 cps	+0.077	"
	1.4974 vdc	14088 cps	14086.8 cps	+0.058	"
	0.9984 vdc	13880 cps	13878.2 cps	+0.086	"
	0.5030 vdc	13672 cps	13669.6 cps	+0.115	"
	0.0000 vdc	13461 cps	13461 cps	0	"
22.0kc	5.0030 vdc	34579 cps	23579 cps	0	"
	4.5030 vdc	23264 cps	23262.8 cps	+0.038	"
	3.9996 vdc	22945 cps	22946.6 cps	-0.051	"
	3.5006 vdc	22631 cps	22630.4 cps	+0.019	"
	3.0000 vdc	22315 cps	22314.2 cps	+0.025	"
	2.4990 vdc	21999 cps	21998.0 cps	+0.032	"
	1.9992 vdc	21683 cps	21681.8 cps	+0.038	"
	1.4974 vdc	21366 cps	21365.6 cps	+0.013	"
	0.9984 vdc	21050 cps	21049.4 cps	+0.019	"
	0.5030 vdc	20376 cps	20373.2 cps	+0.089	"
	0.0000 vdc	20417 cps	20417 cps	0	"
30.0kc	5.0030 vdc	32134 cps	32134 cps	0	"
	3.9996 vdc	31271 cps	31273.0 cps	-0.047	"
	4.5030 vdc	31705 cps	31703.5 cps	+0.035	"
	3.5006 vdc	30842 cps	30842.5 cps	-0.012	"
	3.0000 vdc	30412 cps	30412.0 cps	0	"
	2.4990 vdc	29981 cps	20981.5 cps	-0.012	"
	1.9992 vdc	29550 cps	29551 cps	-0.024	"
	1.4974 vdc	29119 cps	29119.5 cps	-0.012	"
	0.9984 vdc	28689 cps	28690.0 cps	-0-024	"
	0.5030 vdc	28263 cps	28266.5 cps	+0.081	"
	0.0000 vdc	27829 cps	27829 cps	0	"

2.1.6 Total harmonic distortion in the output of each SCO was measured through the test point since the actual outputs were not available.

All units were well within the 1.0% total distortion requirement of the specification, typically 0.45%.

2.1.7 NOISE FEEDBACK ONTO SUPPLY VOLTAGE:

A one ohm (±0.15%) resistor was inserted in series with the +28 vdc supply line to the system. The peak-to-peak voltage across the resistor was measured and recorded. The voltage fed back onto the supply line was 12 millivolts peak-to-peak. The specification allows 30 millivolts peak-to-peak.

2.1.8 AMPLITUDE MODULATION:

The data recorded during pretemperature bench tests was analyzed to determine the amplitude modulation at ambient temperature, and at each supply voltage. AM was calculated as shown below:

$$\% \text{ AM} = \frac{\text{Emax} - \text{Emin}}{\text{Emax} + \text{Emin}} \times 100$$

Amplitude Modulation: The AM at ambient temperature is to be less than 7 1/2%.

		10.5 kc		14.5 kc		22.0 kc		30.0 kc
(+28V)	%AM	1.83	%AM	1.22	%AM	1.34	%AM	4.90
(+32V)	"	1.52	"	1.11	"	1.33	"	4.88
(+24V)	"	1.83	"	1.23	"	1.60	"	5.05
(Overall)	"	1.83	"	1.33	"	1.60	"	5.19

CONCLUSION: All units meet requirements of the specification at ambient temperature.

2.1.9 INPUT IMPEDANCE:

The resistive impedance between the two input leads was measured by making the input circuit part of a 50/50 dc voltage divider. The stimulus voltage producing center frequency (+2.5vdc) was applied to each unit and output frequency was recorded. The upper bandedge stimulus (+5.0 vdc) was then applied through a series decade resistance. The decade was adjusted until +2.5 vdc was present across the input terminals of the SCO, and the output was again at center frequency. These measurements were made at room ambient temperature with +28 vdc supply voltage. The specification requirement is 500k minimum input impedance. These resistances were recorded:

10.5 kc	14.5 kc	22.0 kc	30.0 kc
825 k ohms	833 k ohms	820 k ohms	862 k ohms

2.1.10 FREQUENCY RESPONSE:

The frequency response was determined by measuring the deviation produced by a 5-volt peak-to-peak sine wave at frequencies representing modulation indexes of 5, 2.5, 1, and 0.5, and comparing them with the deviation produced by a 0 to 5 vdc signal. Since the SCO's operate with a 0 to 5 v input range, the sine wave was applied on a 2.5 vdc level. The frequency response is to be within 2% of dc at MI=5 and within 5% out to MI-1.

	DC	MI=5	MI=2.5	MI=1	MI=0.5
10.5 kc	100%	100%	100%	99.3%	93.9%
14.5 kc	100%	100%	100%	100%	86.7%
22.0 kc	100%	100%	100%	97.0%	93.9%
30.0 kc	100%	101.7%	100%	96.5%	93.0%

2.1.11 COMMON MODE REJECTION:

The common mode signals were applied and frequency change was measured at the output of the discriminator's low pass filter as a varying voltage (calibrated for 60v peak-to-peak at 100% dbw).

	10.5 kc	14.5 kc	22.0 kc	30.0 kc
DC	114.0 db	116.0 db	116.0 db	111.0 db
5 cps	81.6 db	81.6 db	81.6 db	77.5 db
10 cps	74.0 db	74.6 db	74.6 db	70.5 db
50 cps	60.0 db	60.8 db	60.8 db	56.5 db
100 cps	54.2 db	54.7 db	54.7 db	50.5 db
200 cps	48.3 db	49.0 db	48.6 db	44.6 db
300 cps	45.0 db	45.5 db	45.5 db	41.5 db
400 cps	43.0 db	43.1 db	43.1 db	38.9 db
500 cps	41.6 db	41.6 db	41.2 db	37.3 db
1000 cps	40.7 db	38.4 db	36.5 db	32.0 db
1500 cps	43.5 db	39.2 db	35.2 db	29.5 db
2000 cps	47.6 db	41.6 db	35.9 db	28.7 db

Conclusions: All four units meet specification requirements for dc common mode rejection (see following graphs). The 10.5 kc unit meet specification requirements for ac common mode rejection; the 14.5 kc and 22.0 kc units were just out of spec at 1 kc (meeting requirements at 2 kc) and the 33.0 kc unit out of spec limits at both 1 kc and 2 kc.

It was observed that by removing the case ground from house ground, a 6 db improvement in CMR was experienced.

2.1.12 CALIBRATE CIRCUITS:

The internal calibration relays were activated and stimulus voltages were applied through the calibration input. It was shown that each unit could be deviated. The current drawn by the relays was also recorded. In addition it was determined at what voltage the relays activated (see below).

Calibrate circuits: (stimulus applied through calibrate lead: relays energized).

	10.5 kc	14.5 kc	22.0 kc	30.0 kc
UBE	11252 cps	15545 cps	23578 cps	32134 cps
FC	10499 cps	14503 cps	21999 cps	29979 cps
LBE	9744 cps	13458 cps	20417 cps	27828 cps

All relays operate at 18 vdc. Total current at +28v - 240 ma (with relays energized).

Total current at +28v = 82 ma (with relays de-energized).

2.2 ENVIRONMENTAL TESTS:

2.2.1 TEMPERATURE TESTS:

2.2.1.1 The system was tested with the lid on the box and the test point monitor leads brought out under the rubber gasket.

2.2.1.1.1 A comprehensive bench test was run on the system prior to subjecting it to the temperature tests.

2.2.1.1.2 The chamber temperature was elevated gradually (over a 15 minute period) to +85°C and the unit was allowed to stabilize at that temperature (1 hour). The following data were recorded at this point: Center frequency and both bandedges (frequency and amplitude) were recorded at each supply voltage. Distortion at center frequency and bandedges at +28 vdc supply. The calibrate relays were than checked for operation at low line voltage (+24 vdc).

2.2.1.1.3 The chamber temperature was reduced to +50°C and the package was allowed to stabilize at that temperature. Output frequency and amplitude were recorded at center frequency and bandedges at +28 vdc.

2.2.1.1.4 The chamber was elevated to a temperature of +110°C. Ten minutes after the chamber temperature stabilized at this temperature, the following data were recorded: Output frequency and amplitude at center frequency and bandedges at all three supply voltages (28 vdc ± 4 vdc) and distortion at center frequency.

2.2.1.1.5 The temperature within the chamber was then reduced over a 15-minute period to -20°C and the unit was allowed to stabilize at this temperature (1 hour). The measurements performed above were repeated except that distortion was deleted and a check of the calibrate relays was substituted.

2.2.1.1.6 The temperature within the chamber was further reduced to -35°C. After 1 hour (stabilization time) the measurements performed in 2.2.1.1.2 were repeated. In addition, B+ was removed from the system for a period of five minutes and them reapplied.

2.2.2 HUMIDITY:

The unit was placed in the humidity chamber and the temperature and humidity were raised to +160°F and 100%. The system was then operated under these conditions for a period of 24 hours. Operation was monitored periodically. No malfunctions were observed.

2.2.3 ACCELERATION:

2.2.3.1 The system was mounted on the arm of the centrifuge and measurements were made (all connections made through slip-rings). The system was then subjected to accelerations of 50g for a three-minute period in each direction of the three major axes. The system operates normally under these accelerations.

2.2.4 ALTITUDE:

The system was placed in a small stainless steel pressure vessel which was in turn connected through a valve to the large NRC space simulator. The NRC chamber was then pumped down to 30 microns (235,000 feet). The valve was then opened and the total pressure stabilized at just over 200,000 feet in less than 2 1/2 minutes. During the fast pulldown, center frequencies of all channels were monitored. The NRC chamber was then pumped down to 6 X 10^{-6} torr and allowed to remain at or near that level for 1 1/2 hours. Center frequency, bandedges and B+ stability were recorded after each half hour. No malfunctions or physical damage was observed.

2.2.5 OXYGEN ATMOSPHERE:

The small vessel containing the system was bled to atmospheric pressure, then purged with dry nitrogen. The vessel was then evacuated to 100 microns. The vessel was then returned to atmospheric pressure with 99.9% pure oxygen. After one hour, the calibrate relays were operated, center frequency, bandedges, and B+ stability were recorded. During this exposure, the +28 vdc supply was removed and reapplied several times. No malfunctions were observed.

2.2.6 SHOCK:

2.2.6.1 The system was rigidly mounted to the drop table and then subjected to three impacts of 50g, 11 milliseconds duration in each direction of the three major axes. SCO outputs were monitored by means of discriminators, recording oscillographs and oscilloscope during each drop. Operation of the calibrate relays was checked before and after each drop. The system operated normally.

2.2.7 VIBRATION:

The system was rigidly mounted to the vibration table and subjected to the following vibration tests.

a. Random, 3 sigma cut-off, 15g rms for 15 seconds/axis with the following spectral power density:

   10 cps - 0.573g 2/cps increasing to 0.1607 g^2/cps at 75 cps

   75 to 220 cps - 0.1607 g^2/cps flat

   2020 cps - 0.0573 g^2/cps decreasing from 0.1607 g^2/cps at 220 cps.

b. Random, 3 sigma cut-off, 12g rms for 180 seconds/axis with the following spectral power density:

   10 cps - 0.0367g^2/cps increasing to 0.1038 g^2/cps at 75 cps

75 to 220 cps - 0.1038 g^2/cps flat

2020 cps - 0.0367 g^2/cps decreasing from 0.1038 g^2/cps at 220 cps.

No malfunctions were observed.

2.2.8 ACOUSTIC NOISE:

The system was exposed to a sound pressure level of 160 db overall for a period of 6 minutes. The upper bandedge was monitored on each SCO every minute for the first four minutes. During the 6th minute of exposure center frequency, both bandedges and the calibrate relays were checked. No malfunctions were observed.

2.2.9 SALT SPRAY:

The system was subjected to the salt spray test of MIL-STD-810, Method 509 except for an exposure time of 24 hours. The system was satisfactorily operated within 1/2 hour of removal from the chamber.

2.3 RADIO FREQUENCY INTERFERENCE:

The system was subjected to the tests of MIL-I-26600 at ARK Electronics Corp., Willow Grove, Pa. Detailed results are included in the ARK test report. A brief summary is listed below:

a. CW radiated: 150 kc to 1000 mc

Steady state: complies

* Transient: Within 20 db upgrade (Para. 3.1.2, MIL-I-26600)

b. Broadband radiated: 150 kc to 400 mc

Steady state: Complies

* Transient: Within 20 db upgrade (Para. 3.1.2, MIL-I-26600).

* Operating calibrate relays, probably largely due to noise from external switch.

c. CW conducted: 150 kc to 25 mc

Power lines: Complies

Stimulus lines: Complies

d. Broadband conducted: 150 kc to 25 mc

Power lines: Complies

Stimulus lines: Complies

e. Susceptibility:

Audio conducted: Complies

RF conducted: Complies

RF radiated: Not performed

f. Conducted transients:

Power lines: Complies

Stimulus lines: Complies

CSA output: Complies

3.0 THERMAL TEST RESULTS:

The data taken from a typical four-channel telemetry modulation system, serial number 004, is presented next in the normal computer print-out format used by the Telemetry Systems Section. Such print-outs are available on each flight-qualified telemetry system produced at MSC.

DYMEC CHANNEL 12 VCO CENTER FREQUENCY 10500.00 DATE 9/10/64 SERIAL NO. 5

SENSITIVITY LOWER BAND EDGE = -0.628 CENTER FREQUENCY = -0.595 UPPER BAND EDGE = -0.430

	24V B+ LEVEL		28V B+ LEVEL		32V B+ LEVEL	
TEMP	NON-LINEARITY	AMPLITUDE MODULATION	NON-LINEARITY	AMPLITUDE MODULATION	NON-LINEARITY	AMPLITUDE MODULATION
78	0.000	0.838	0.066	0.836	0.066	0.775
150	0.100	0.478	0.100	0.360	0.033	0.359
0	0.066	0.896	0.033	0.837	0.066	0.893
78	0.099	0.022	0.066	0.022	0.099	0.140

AMPLITUDE VARIATION

	24V B+ LEVEL			28V B+ LEVEL			32V B+ LEVEL		
TEMP	LBE	CF	UBE	LBE	CF	UBE	LBE	CF	UBE
78	-0.152	-0.120	-0.156	0.000	0.000	0.000	0.000	0.000	0.122
150	-0.607	-0.481	0.108	-1.062	-0.842	-0.116	-0.998	-0.602	-0.048
0	4.234	4.212	4.108	4.266	4.332	4.264	4.417	4.452	4.298
78	1.750	2.527	3.511	1.902	2.647	3.667	1.815	2.768	3.823

B+ STABILITY FREQUENCY STABILITY B+ STABILITY

	24V B+ LEVEL			28V B+ LEVEL			32V B+ LEVEL		
TEMP	LBE	CF	UBE	LBE	CF	UBE	LBE	CF	UBE
78	0.066	0.000	0.066	0.000	0.000	0.000	0.000	0.000	0.000
150	0.000	0.066	0.132	-0.198	-0.463	-0.793	0.000	-0.066	0.000
0	0.000	0.066	0.066	0.066	0.132	0.264	0.000	0.000	-0.066
78	0.000	0.066	0.066	-0.132	-0.132	-0.132	0.000	0.000	-0.066

DYMEC CHANNEL 13 VCO CENTER FREQUENCY 14500.00 DATE 9/10/64 SERIAL NO. 45

SENSITIVITY LOWER BAND EDGE = -0.311 CENTER FREQUENCY = -0.479 UPPER BAND EDGE = -0.359

	24V B+ LEVEL		28V B+ LEVEL		32V B+ LEVEL	
TEMP	NON-LINEARITY	AMPLITUDE MODULATION	NON-LINEARITY	AMPLITUDE MODULATION	NON-LINEARITY	AMPLITUDE MODULATION
78	0.096	0.707	0.144	0.510	0.120	0.509
150	0.144	0.644	0.144	0.578	0.120	0.511
0	0.096	0.075	0.120	0.075	0.120	0.075
78	0.144	0.075	0.120	0.075	0.144	0.075

AMPLITUDE VARIATION

	24V B+ LEVEL			28V B+ LEVEL			32V B+ LEVEL		
TEMP	LBE	CF	UBE	LBE	CF	UBE	LBE	CF	UBE
78	-0.027	-0.130	-0.420	0.000	0.000	0.000	0.184	0.259	0.186
150	-0.341	-0.389	-0.606	-0.313	-0.259	-0.448	-0.157	-0.130	-0.159
0	3.619	4.280	4.839	3.803	4.540	5.026	4.116	4.799	5.343
78	1.159	1.816	2.350	1.316	1.946	2.509	1.472	2.075	2.667

B+ STABILITY FREQUENCY STABILITY B+ STABILITY

	24V B+ LEVEL			28V B+ LEVEL			32V B+ LEVEL		
TEMP	LBE	CF	UBE	LBE	CF	UBE	LBE	CF	UBE
78	0.096	0.048	0.096	0.000	0.000	0.000	0.000	-0.048	-0.048
150	0.000	0.048	0.096	-0.048	-0.191	-0.335	0.000	-0.048	-0.048
0	0.048	0.048	0.096	-0.383	-0.527	-0.622	0.000	0.000	0.000
78	0.048	0.096	0.096	-0.144	-0.191	-0.191	0.000	0.000	-0.048

DYMEC CHANNEL 14 VCO CENTER FREQUENCY 22000.00 DATE 9/10/64 SERIAL NO. 85

SENSITIVITY LOWER BAND EDGE = -0.694 CENTER FREQUENCY = -0.505 UPPER BAND EDGE = -0.316

	24V B+ LEVEL		28V B+ LEVEL		32V B+ LEVEL	
TEMP	NON-LINEARITY	AMPLITUDE MODULATION	NON-LINEARITY	AMPLITUDE MODULATION	NON-LINEARITY	AMPLITUDE MODULATION
78	0.032	0.603	0.000	0.540	0.048	0.535
150	0.032	1.597	0.000	1.341	0.032	1.277
0	0.032	0.466	0.063	0.529	0.032	0.529
78	0.032	0.003	0.048	0.002	0.063	0.067

AMPLITUDE VARIATION

	24V B+ LEVEL			28V B+ LEVEL			32V B+ LEVEL		
TEMP	LBE	CF	UBE	LBE	CF	UBE	LBE	CF	UBE
78	-0.132	-0.114	-0.257	0.000	0.000	0.000	0.132	0.114	0.143
150	0.356	-0.569	-1.742	0.658	-0.114	-0.941	0.790	0.000	-0.684
0	2.585	3.982	4.670	2.736	4.209	4.957	2.848	4.209	5.071
78	1.339	1.934	2.435	1.471	2.048	2.578	1.509	2.275	2.750

B+ STABILITY FREQUENCY STABILITY B+ STABILITY

	24V B+ LEVEL			28V B+ LEVEL			32V B+ LEVEL		
TEMP	LBE	CF	UBE	LBE	CF	UBE	LBE	CF	UBE
78	0.032	0.095	0.095	0.000	0.000	0.000	0.000	0.032	-0.032
150	0.126	0.253	0.316	0.600	0.631	0.663	0.000	0.000	-0.063
0	0.063	0.032	0.063	-0.979	-0.947	-1.042	0.032	-0.032	-0.032
78	0.063	0.063	0.095	-0.158	-0.126	-0.189	0.000	0.000	-0.032

DYMEC CHANNEL 15 VCO CENTER FREQUENCY 30000.00 DATE 9/10/64 SERIAL NO. 126

SENSITIVITY LOWER BAND EDGE = 0.139 CENTER FREQUENCY = 0.046 UPPER BAND EDGE = -0.069

	24V B+ LEVEL		28V B+ LEVEL		32V B+ LEVEL	
TEMP	NON-LINEARITY	AMPLITUDE MODULATION	NON-LINEARITY	AMPLITUDE MODULATION	NON-LINEARITY	AMPLITUDE MODULATION
78	0.000	0.733	-0.012	0.947	0.012	1.000
150	0.012	0.571	0.012	0.841	0.023	0.784
0	-0.070	1.823	-0.070	1.924	-0.093	1.918
78	0.023	1.290	0.012	1.446	0.012	1.441

AMPLITUDE VARIATION

	24V B+ LEVEL			28V B+ LEVEL			32V B+ LEVEL		
TEMP	LBE	CF	UBE	LBE	CF	UBE	LBE	CF	UBE
78	-0.193	-0.437	-0.620	0.000	0.000	0.000	0.111	0.000	0.218
150	-0.478	-0.765	-1.222	-0.264	-0.219	-0.474	-0.021	-0.109	-0.346
0	3.784	4.153	5.619	3.825	4.372	5.875	4.089	4.590	6.130
78	1.746	2.186	2.446	1.898	2.404	2.920	2.141	2.514	3.157

B+ STABILITY FREQUENCY STABILITY B+ STABILITY

	24V B+ LEVEL			28V B+ LEVEL			32V B+ LEVEL		
TEMP	LBE	CF	UBE	LBE	CF	UBE	LBE	CF	UBE
78	0.139	0.231	0.301	0.000	0.000	0.000	-0.023	-0.023	-0.069
150	0.208	0.370	0.532	0.069	0.046	-0.023	-0.023	-0.023	-0.046
0	0.069	0.069	0.069	-0.556	-0.810	-0.949	0.000	-0.046	-0.046
78	0.139	0.231	0.301	-0.278	-0.278	-0.324	-0.023	-0.023	-0.023

4.0 CONCLUSIONS:

The telemetry system described in this report is one having many versatile features, such as:

a. Differential inputs which can be used with common mode voltages of up to 50 volts. This can simplify signal conditioning many times.

b. The input signal grounds are separated from the power grounds and chassis grounds by way of a dc-to-dc power supply in each subcarrier module.

c. The components and system are undamaged by power supply polarity reversal.

d. Overvoltages of up to 28 volts on the input signal circuitry will not cause one channel to interfere with an adjacent channel.

e. There are absolutely no adjustments or controls on the VCO's. This yields an obvious field maintenance advantage and a large increase in reliability.

e. The VCO's have a miniaturized calibrate relay housed in each VCO module which eliminates the need for external chassis mounting and wiring of relays.

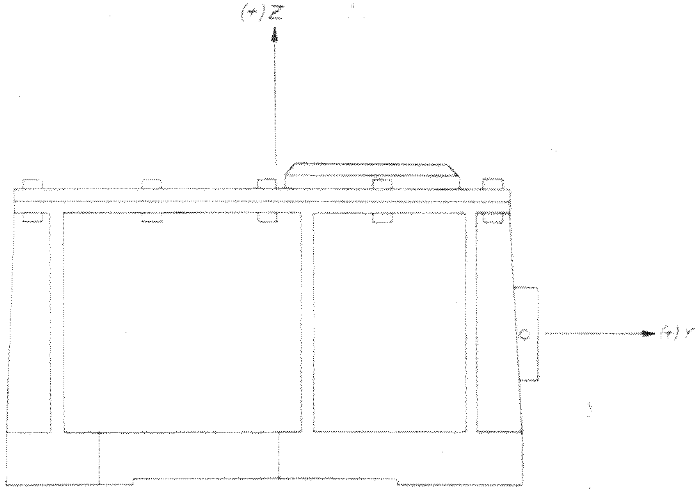
f. The system packaging is extremely rugged and humidity and salt fog proof. This yields a wide range of uses and applications for the system. Humidity is controlled and monitored by an indicator-dessicator installed in the lid of the package.

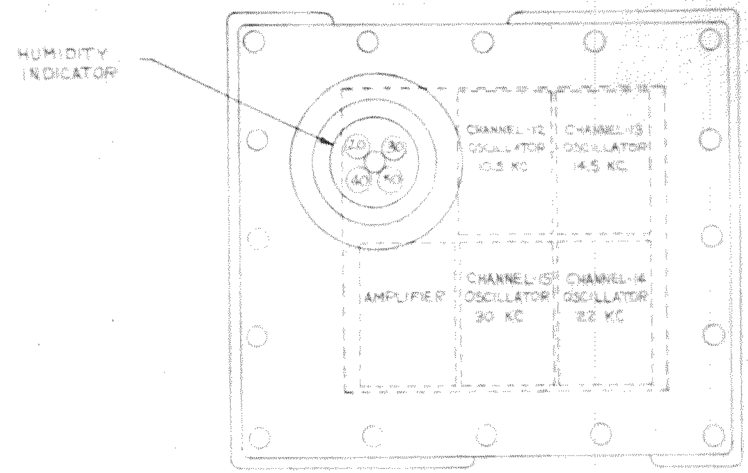
g. The thermal extremes are -35C to 110C with exceedingly small frequency drift or amplitude modulation (see computer data). This represents a great increase in performance compared with the early boilerplate telemetry systems.

h. The output amplifier circuitry is a balanced output. This is an advantage in that common mode noise on the spacecraft harnessing is rejected. In addition, this allows no interconnection of output signal grounds and shield or power grounds unless such grounding practice is preferred.

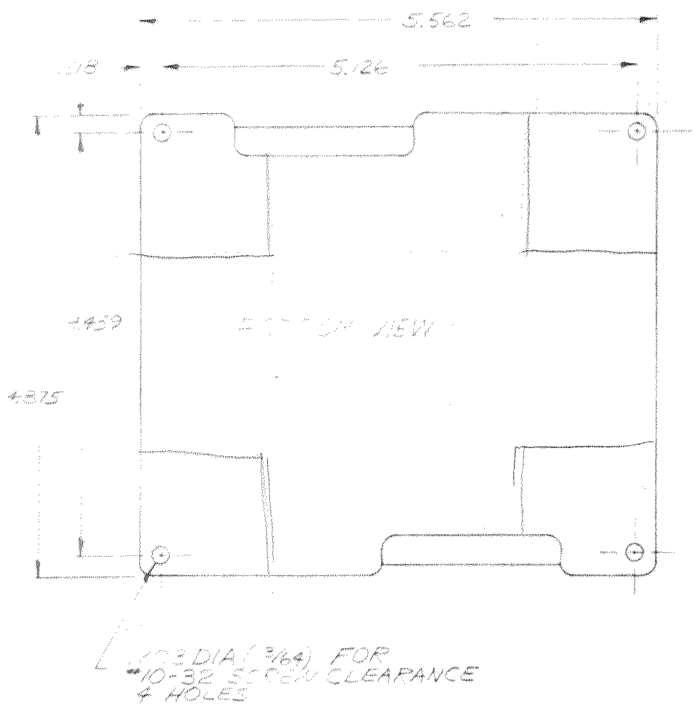
i. The VCO's are fabricated with only one minor departure from MSFC-PROC-158B.

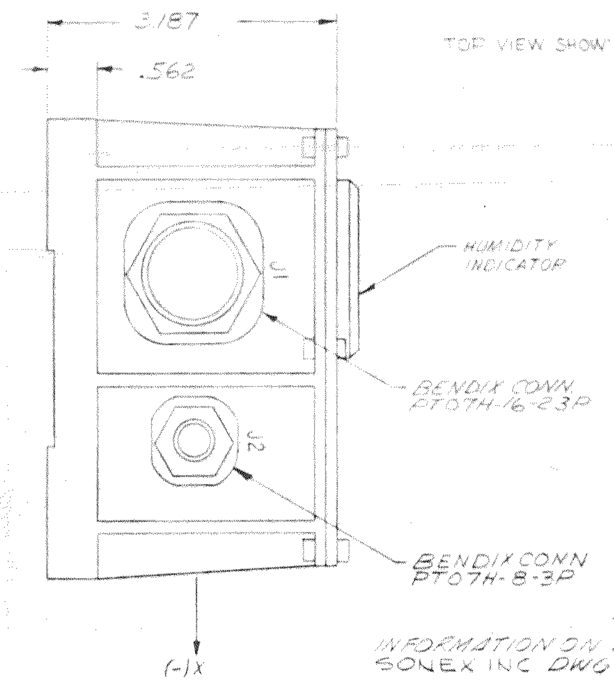
LET	DATE	REVISIONS	BY
A	6-30-64	ADDED TOP VIEW TO DWG.	HOSKINS, KW
B	9-2-64	INC. E.O. EE453	[illegible]





TOP VIEW SHOWING COMPONENT LOCATION





SC- 510577 REV. B

INFORMATION ON THIS DWG TAKEN FROM SONEX INC DWG # D300-2009D

NTN 3.11.1.1.1

ITEM	REQD.	DESCRIPTION	
APPROX WT. 3.8 POUNDS	SCALE 1/1	MANNED SPACECRAFT CENTER HOUSTON, TEXAS	
DIMENSIONAL TOLERANCE UNLESS NOTED OTHERWISE 1 DECIMAL PLACE ± .10 2 DECIMAL PLACES ± .02 3 DECIMAL PLACES ± .005 ANGULAR ±	DR. HOSKINS KW 6.30.64 DES. APP. [illegible] 6.30.64 APP. [illegible] 6.30.64	TAPE MODULATION PACKAGE OUTLINE	
SURFACE FINISH IN MICROINCHES RMS UNLESS NOTED OTHERWISE √	PROJECT APOLLO R&D	SC- 510577	REV. B

ENGINEERING DRAWING FORMAT (SC-)

FORM 556C (SEP 62) RIDGWAY'S RECORDER 10601C